Development of Airport Noise Mapping using Matlab Software (Case Study: Adi Soemarmo Airport – Boyolali, Indonesia)

by Haryono S. Huboyo

Development of Airport Noise Mapping using Matlab Software (Case Study: Adi Soemarmo Airport – Boyolali, Indonesia)

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Abstract. Noise is considered as one of the main environmental impact of Adi Soemarmo International Airport (ASIA), the second largest airport in Central Java Province, Indonesia. In order to manage the noise of airport, airport noise mapping is necessary. However, a model that requires simple input but still reliable was not available in ASIA. Therefore, the objective of this study are to develop model using Matlab software, to verify its reliability by measuring actual noise exposure, and to analyze the area of noise levels.. The model was developed based on interpolation or extrapolation of identified Noise-Power-Distance (NPD) data. In accordance with Indonesian Government Ordinance No.40/2012, the noise metric used is WECPNL (Weighted Equivalent Continuous Perceived Noise Level). Based on this model simulation, there are residence area in the region of noise level II (1.912 km^2) and III (1.16 km^2) and 18 school buildings in the area of noise levels I, II, and III. These land-uses are actually prohibited unless noise insulation is equipped. The model using Matlab in the case of Adi Soemarmo International Airport is valid based on comparison of the field measurement (6 sampling points). However, it is important to validate the model again once the case study (the airport) is changed.

1 Introduction

Adi Sumarmo International Airport (ASIA) is the second largest airport in Central Java Province, Indonesia. It is located in Boyolali, around 14 km away from Surakarta City. It served 1,412,638 passengers in 2015 [1]. Some extra flights is always added during Hajj season and Ramadhan season. Different with Achmad Yani International Airport (AYIA) - Semarang, ASIA is located on land far from the sea. It is built near Waduk Cengklik (Cengklik Reservoir). Due to the airport operation, noise cannot be avoided, particularly from the aircrafts departures and landing (approaches).

Many researches have proved that noise from the airport could bring negative impact, such as annoyance [2], sleep disturbance [3], insomnia and daytime hypersomnia [4], myocardial infarctions [5], children's development [6], [7], psychosomatic effects [8], chronic noise stress and hypertension [9], and immune system [10]. In the vicinity of ASIA, it is reported that 65% of the inhabitants in the region suffered from sleep disturbance, hearing impairment, and annoyance based on Hartono's research in 2006 [10]. The aircraft noise impact on immune system has been also investigated by Hartono [10] that there was a significant effect of the aircraft noise level to the number of Natural Killer Cell (CD56+CD16+CD3-) among people in the area of Adi Sumarmo Airport Boyolali.

The scientific evidence of aforementioned negative impacts due to aircraft noise exposure must be avoided by properly managing the airport operation. In order to identify whether there is higher noise exposure than the standard limit around the airport, airport noise mapping is necessary. The airport noise mapping can be estimated by a model. The FAA (Federal Aviation Administration) has developed INM (Integrated Noise Model) and AEDT (Aviation Environmental Design Tool). However, these tools require advanced understanding on aircraft specification and operation. Therefore, another model using simplified input data was needed to be developed, particularly adjusted to the condition of airports in Indonesia. The objective of this study are to develop model using Matlab and to verify its reliability by measuring actual noise exposure.

2 Methods

2.1. Airport specification

Adi Sumarmo International Airport (ASIA) is one of the airport operated by PT Angkasa Pura I (Persero) with service area of Surakarta City, Boyolali, Sukoharjo, Karanganyar, Sragen, Klaten, Wonogiri, a part of districts in East Java Province (Ngawi, Magetan, Pacitan, and Ponorogo District). ASIA is located at coordinate 07 31' 04"S 110 45'18"E with relatively flat topography (1-2%) and elevation of 128 meters above sea level. The temperature at ASIA is relatively constant, the minimum average temperature annually is from 20,6ºC to 22,8ºC,

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while maximum is from 31,7ºC to 32,8ºC. The maximum wind velocity monthly is 5 knot (8 km/hr) while minimum 2 knot (3.2 km/hr) with prevailing wind N240E.

At ASIA, there are two runways, i.e. Runway-08 (7°31'06.4"S 110°44'47.4"E) and Runway-26 (7°30'48.6"S 110°46'07.1"E), with dimension of 2600 m x 45 m. This airport also serves extra flights to Mecca and Jeddah during Hajj season. In this study, the busiest schedule during regular time was selected as case study, i.e. September 15th, 2016 (22 approaches and 22 departures). The operational hours during the day was from 06.00 – 20:40 Western Indonesia Time (GMT+07h).

2.2 Model Development

The first step in this modeling was to determine the layout area and grids in the layout so that the coordinate of each grid can be determined. Coordinates denoted by x, y, and z. Coordinate-x is the coordinate in the direction of the runway, coordinate-y represents the coordinate of perpendicular to the runway, and coordinate-z shows the coordinates of the height of the surface (ground level). Furthermore, flight tracks and flight profile were defined. Flight track data obtained from ASIA were used to determine the position of the aircraft (the sound source). Meanwhile, the flight profiles were obtained from the flight profile, i.e. Aircraft Noise Performance (ANP) database. Flight profile data shows the relationship between altitude of aircraft with aircraft horizontal distance from the runway during landing or take-off.

The calculation step was started from the altitude of aircraft during landing (approach) or take-off (departure). To calculate the altitude at each grid from flight profile data, interpolation or extrapolation is necessary [11].

$$z(x) = z(x_i) + \frac{z(x_{i+1}) - z(x_i)}{x_{i+1} - x_i} . (x - x_i) \qquad (1)$$

where, $z(x)$: aircraft altitude at the observed grid point; $z(x_i)$: aircraft altitude at lower grid point; $z(x_{i+1})$: aircraft altitude at higher grid point; x: aircraft distance from the runway at the observed grid point; x_i: aircraft distance from the runway at closer grid point; x_{i+1}: aircraft distance from the runway at further grid point.

The next step was to calculate the distance between aircraft and each grid. The distance is the closest distance between line on flight profile with grid.

$$d = \sqrt{(x_a - x_o)^2 + (y_a - y_o)^2 + (z_a - z_o)^2} \qquad (2)$$

where, d: distance between aircraft and observed grid; x_a: coordinate-x of the aircraft; x_o: coordinate-x of the observed grid; y_a: coordinate-y of the aircraft; y_o: coordinate-y of the observed grid; z_a: coordinate-z of the aircraft; z_o: coordinate-z of the observed grid.

After the calculation of the distance in each grid has been done, the noise level of each grid was calculated using Noise-Power-Distance (NPD) data. Interpolation or extrapolation at logarithmic scale was undertaken to calculate the noise level of the grid that previously unknown. According to ICAO [11], to determine the noise level at grid between two grids that have previously known, the interpolation could be calculated as equation (3). Meanwhile, extrapolation should be done when the observed grid was beyond the other two grid that have been known its noise levels. If the distance (d) is shorter than the shortest distance in NPD data (d_i), then the equation (4) should be done, while if (d) is larger than the largest distance in NPD data (d_i), then the calculation was done by equation (5).

$$L(d) = L(d_i) + \frac{L(d_{i+1}) - L(d_i)}{\log d_{i+1} - \log d_i} \cdot (\log d - \log d_i) \qquad (3)$$

$$L(d) = L(d_2) + \frac{L(d_1) - L(d_2)}{\log d_2 - \log d_1} \cdot (\log d_2 - \log d) \qquad (4)$$

$$L(d) = L(d_{i-1}) + \frac{L(d_{i-1}) - L(d_i)}{\log d_i - \log d_{i-1}} \cdot (\log d - \log d_{i-1}) \qquad (5)$$

where, $L(d)$: noise level at the observed grid point; $L(d_i)$: noise level at lower grid point than the observed grid point; $L(d_{i+1})$: noise level at higher grid point than the observed grid point; $L(d_1)$: noise level at the first point in NPD data; $L(d_2)$: noise level at the second point in NPD data; $L(d_i)$: noise level at the last point in NPD data; $L(d_{i-1})$: noise level at the second latest in NPD data; d: distance from grid point to aircraft in the observed grid point; d_i: distance from grid point to aircraft that shorter than the observed grid point; d_{i+1}: distance from grid point to aircraft that further than the observed grid point; d_1: distance from the aircraft at the first point in NPD data; d_2: distance from the aircraft to the second point n NPD data; d_i: distance from the aircraft to the last point in NPD data; d_{i-1}: distance from the grid point to the second latest in NPD data.

After all of noise levels of grids has been calculated, WECPNL (Weighted Equivalent Continuous Perceived Noise Level) as the noise metric should be used in accordance with Indonesian Government Ordinance No.40/2012. In this study, a day simulation (September 15th, 2016) was undertaken. WECPNL can be calculated as the following equation based on Indonesian National Standard, SNI 8150:2015:

$$\mathrm{WECPNL} = \overline{\mathrm{dB(A)}} + 10 \log \mathrm{N} - 27 \qquad (6)$$

$$\overline{\mathrm{dB(A)}} = 10 \log[\,(\tfrac{1}{n}) \textstyle\sum_{i=1}^{n} 10^{\mathrm{Li}/10}] \qquad (7)$$

$$\mathrm{N} = \mathrm{N2} + 3\ \mathrm{N3} + 10\ (\mathrm{N1} + \mathrm{N4}) \qquad (8)$$

where, $\overline{\mathrm{dB(A)}}$ means the energy averaged maximum A-weighted sound levels (L_i) of noise events N. The noise events include the number of approaches and departures of aircrafts. N_1, N_2, N_3, and N_4 mean the numbers of noise events observed during the night-early morning

(00:00-07:00), the day-time (07:00-19:00), evening (19:00-22:00), night-time (22:00-00:00), respectively. Calculating dB(A) requires n and Li observed during 24 hours. The total number of departures and approaches during 24 hours is denoted by n while Li means the maximum measured noise level (A-weighted) during one noise event.

2.3 Programming steps

The program was developed in Bahasa Indonesia (Indonesian Language) instead of English so that Indonesian could easily understand how to input the data needed. The initial step in programming using Matlab is by designing function m-file to read or process data used in the simulation, then the process of calculating and creating the contours and the output process both the noise contour map and the noise levels at the determined points.

The input data includes length of runway, number of flights, operation type (approach or depart), flight direction (right or left), and flight time schedule. The calculation and creating the contour process were done in m-file. The contour map can be saved as *.jpg format. All of these processes are integrated in GUI (Graphical User Interface) program.

2.4 Validation of the model

This study used ASIA as a case study, hence, validation of the model was undertaken using the data from the airport. In this case, the WECPNLs generated from the model were compared to the WECPNL measured in the field. WECPNL needs Li or the maximum A-weighted sound levels (L_i) of each noise event such as take-off (departure) or landing (approach) of an aircraft. There were 6 locations of sampling point in the vicinity of ASIA, e.g. 4 points crossing the runway (residence area) and 2 points in school area (see Fig. 1). The model is considered to be accurate if >75% of sampling points have ΔWECPNL<5.

Fig. 1. Location of noise sampling points

In this study, the background noise levels (A-weighted) during noise sampling were also measured then Leq was used as the noise metric. The method was based on the Indonesian Ministry of Environment Decree No. 48/Menlh/11/1996 regarding Noise Level Standard. The measurement was done using Sound Level Meter Extech RS232 (at S2), Lutron-4010 (at P1 and P4), Benetech GM1351 (at P2, P3, and S1). All of the equipment have been checked its accuracy. Leq calculation is as follows:

$$L_{eq} = 10\log\left(\sum_{i=1}^{n}(fi.10^{Li/10})\right) \qquad (9)$$

where fi = time fraction during measurement, Li = dBA value, n = total measurement during one period.

3 Results and discussion

3.1 Simulations of the model

The simulation was based on the data during busiest schedule in September 2016. There were 22 departures and 22 approaches, starting from 06.00 to 20.40 GMT+7h. GUI for inputting the data can be seen in Fig. 2.

According to the Indonesian Government Ordinance No.40/2012, the evaluation of noise levels in the vicinity of airport is based on the area in each category level noise region, namely region level I, II, and III. The total area of this noise region is 12.8 km^2. The area of noise region level I, II, and III are 6.4, 2.27, 4.13 km2, respectively. Directions distribution of the noise region extends toward Runway-26 as far as 10.34 km and 8.71 km from Runway-08 and 0.92 km from each runway side. For details, the noise contour map can be seen in Fig. 3.

Noise region level I can be used for various types of activities and / or building unless the type of building hospitals and schools. Noise region level II can be used for various types of activities and / or building unless the type of building hospitals, schools, and residence area. Meanwhile, the noise region level III can only be used to build airport facilities which are equipped with sound insulation and can be used also as a green belt or a means of controlling the environment and agriculture which are not inviting birds.

However, based on this model simulation, there are residence area in the region of noise level II (1.912 km^2) and III (1.16 km^2) as well as the school buildings in the area of noise levels I, II, and III. There are 18 schools in total, namely 8 schools in level I, 5 schools in level II, and 5 schools in level III. Unfortunately, schools and residence area are still not insulated from aircraft noise exposure properly.

3.2 Validation of the model

It is important to validate the model, how far the model is accurate. In this case, 6 sampling points were selected to identify whether the WECPNL in the model is accurate compared to the actual noise measurement. Table I represents the results. It is clear that only P3 has ΔWECPNL>5. Therefore, the model is considered valid

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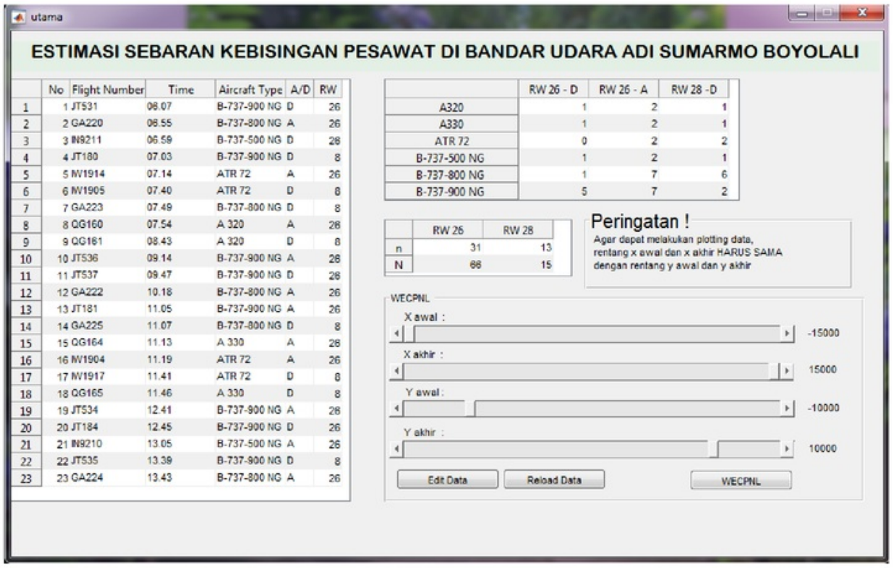

Fig. 2. Graphical User Interface (GUI) developed in Indonesian Language for data input

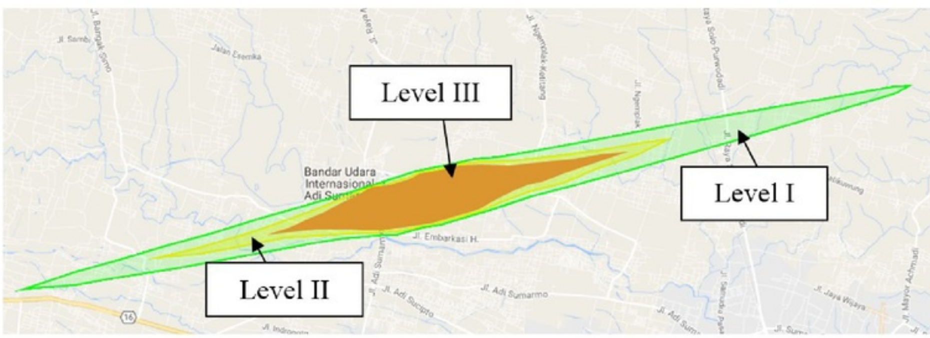

Fig. 3. Noise contour map of Adi Soemarmo International Airport

in this case. However, if the model is to be implemented at other airports, the model should be re-checked to make sure that the error is within the acceptable limit. Because, in other case, such as Husein Sastranegara International Airport – Bandung, the model using Matlab was not considered accurate because several aspects such as bank angel, atmospheric, absorption adjustment, acoustic impedance adjustment, noise fraction adjustment, duration adjustment, lateral attenuation adjustment, and line-of sight blockage adjustment, were not considered properly [12].

Table 1. Comparison between model and field measurement

No	Point	Background Noise (Leq) during 15 hours of sampling dB(A)	WECPNL		ΔWECPNL
			Model	Field measurement	
1.	P1	59,70	83,25	80,93	2,31
2.	P2	59,29	69,25	64,28	4,96
3.	P3	67,46	87,31	79,0359	8,28
4.	P4	54,31	65,71	65,27	0,44
5.	S1	58,93	74,69	74,54	0,14
6.	S2	48,49	82,54	83,49	-0,95

4. Conclusions

The total area of this noise region is 12.8 km^2. The area of noise region level I, II, and III are 6.4, 2.27, and 4.13

km^2, respectively. Directions distribution of the noise region extends toward Runway-26 as far as 10.34 km and 8.71 km from Runway-08, and 0.92 km from each runway side. The model using Matlab in the case of Adi Soemarmo International Airport is valid based on comparison of the field measurement (6 sampling points). However, it is important to validate the model once the case study (the airport) is changed. For example, the model developed in this study was specified for Adi Soemarmo International Airport, then it will not appropriate to model the noise in other airports. Therefore, in the next study, the model could be developed more detail to consider the neglected factors and user input for adjustment of the airport specification.

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